

chromosphere and which ultimately derive their energy from the accretion of hot gas by the Galaxy. Whether the flux of ionizing photons is sufficient depends on its unknown spectrum, but in principle there would be enough flux available.

A further possibility is that sufficient photons may enter the disk of the Galaxy to contribute appreciably to the overall ionization rate of the interstellar medium. We know from the work of Bergeron and Souffrin¹⁵ and of Habing and Goldsmith¹⁶ that if the disk is ionized by ~ 100 eV photons then we would need a primary hydrogen ionization rate $\sim 10^{-16}$ s⁻¹ to account for the observed ionization state and temperature of the interstellar medium. The actual ionization mechanism is still not known. A likely possibility is radiation from the discrete galactic soft X-ray sources discussed by Gorenstein and Tucker¹¹ and by Davidsen *et al.*¹⁷. However, radiation from the galactic chromosphere is an alternative possibility which might be important close to the edge of the disk.

As a final speculative remark I would mention the possibility that it is the inflowing material which is responsible for the confinement of the interstellar magnetic field and cosmic rays to the disk of the Galaxy. This is dynamically reasonable since with our accretion parameters the internal and ram pressures of the incoming material $\sim 10^{-12}$ dyne cm⁻² near the disk. I hope to return to this dynamical question elsewhere.

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Is There a Tenth Planet in the Solar System?

We have been analysing the longitudinal residuals of Neptune (N), partly from sheer interest aroused by the discordance between the pre-discovery position of N and its currently accepted orbit¹ and because colleagues (already conducting a photographic hunt for a hypothetical tenth planet) sought our assistance in narrowing the field of search by using perturbation theory.

Seidelmann² has ruled out any of three possible outer planets—and Brady's suggestion³ of a planet of Jovian mass at about 60 AU seems hardly possible, because its effect on Uranus (U) and N (easily computed from ref. 4, Fig. 4) would be larger by orders of magnitude than any residual observed since the mid nineteenth century. Further, a search by Foss *et al.* has failed to find it⁵. We therefore decided to attempt to

establish the limits of the possible position of a tenth planet, working from data on N.

N was chosen as the main basis for the work because it is the most sensitive of the known planets to the pull of a possible exterior body⁴ and the least affected by existing uncertainties in the masses of its known planetary neighbours. As a check on the working, data from Uranus (U) were also used; and cases where the results from these two sources were markedly different were rejected.

A least-squares differential analysis was carried out, assuming circular orbits for any perturbing body. This assumption was made because it is reasonable *a priori*, and because it was decided that the N data were insufficient to indicate reliably the extra unknowns involved in an elliptical path. (A paper giving full details of the work is in preparation.)

The only satisfactory solutions found were for bodies whose orbits lay between 50 and 100 AU from the Sun, and whose positions at 1973.0 lay within a relatively small sector of the ecliptic. The range of such possible bodies is shown in Table 1.

Table 1 Limits of Solutions for a Possible Tenth Planet

Radius of orbit (AU)	Longitude limits (2 s.d.)	Mass ± 1 s.d.
75	309°–320°	5 \pm 2
60	322°–343°	3 \pm 1
50	338°–5°	2 \pm 1

Masses are in Sun/206265.
(Epoch: 1970.0; E and E 1950.0.)

These results and N's latitude residuals were used to find latitude solutions. Unfortunately, however, the standard deviations of the latitude results are large, and the confidence intervals correspondingly so (Table 2).

Table 2 Latitude Solutions for Various Radius and Longitude Values

Radius of orbit (AU)	Longitude	Latitude ± 1 s.d.
75	310°	-17° \pm 37°
	320°	-27° \pm 40°
60	320°	+ 6° \pm 8°
	340°	+30° \pm 17°
50	350°	+14° \pm 6°
	0°	+20° \pm 10°

Seidelmann² rejected 3 trial planets, as the only one which accounted for the 1795 residual forced unacceptably large ones upon N's motion since 1846. A body falling within our range, however, satisfies the former whilst only requiring disturbances of amplitude ca. 0.05 s in the post-1846 data.

Nevertheless we do not definitely assert that such a planet exists. Our set task, which we consider we have performed, was to delimit the possible space wherein it might be.

If the current search in this area finds nothing, then the indication becomes strong that the major bodies of the solar system end at N, a matter bearing critically upon theories of the origin of the solar system.

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